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TEMPORAL AND SPATIAL CHANGES OF SOIL MOISTURE IN ARTIFICIAL FOREST GAPS IN WESTERN HUNGARY

by

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ABSTRACT

One of the greatest challenges of continuous cover forest management is to choose a suitable gap size in a given forest stand that will help with the regeneration of economically significant woody species, but possibly control the competitors of the cutting site and undesired woody species.

The soil moisture patterns of a forest floor, both on the spatial and temporal scales have great impact on the continuous cover forest management. The experiments cover the mapping of soil moisture conditions in various bearing gaps (East-West, and North-South) at two sites in western Hungary. One site is in Bejcgyertyános in a hornbeam-Sessile oak (*Carpinus betulus-Quercus petraea)* forest, the other site is in Vép in a turkey oak (*Quercus cerris*) forest. The distance between the two sites is about 17 km, so the weather conditions are almost similar. The spatial variability of the soil-moisture time-series shows a characteristic pattern during the growing season. The study shows relatively dry (2013) and relatively moist (2014) vegetation seasons. There are significant differences in the different parts of a gap, in the research sites, Volumetric Water Content is 6 percent higher in the middle of a gap than in the sides of it. The soil moisture is additional 2 percent lower above close canopy.

Keywords: gap, continuous cover forest management, soil-moisture time-series

1 INTRODUCTION

In Hungary, one of the greatest questions of forest management is “how to transform a clear cutting forest to a selection cutting forest” (Koloszár, 2005). The selection cutting forest is a special forest stand shape (forest scape), which is established by the long-time continuous selection cutting (harvesting or intervention of stems) (Solymos, 2000). The ideal picture of an uneven aged, mixed stand is shown in *Figure 1* by Roth.

Figure 1 **–** The ideal picture of uneven aged, mixed selection cutting stand (Roth, 1935).

For the growing of seedlings it is an indispensable assumption to have the adequate environmental parameters such as hydrological or light conditions. In gaps opened in closed forest stands, the soil moisture relations are changing, the gaps are watered. The diversity of soil moisture is high between the centre of a gap and the surrounding closed forest stand (Van Dam, 2001). To show this diversity of soil moisture in temporal and spatial scale, more measurements are required. In Hungary extensive studies of gap regeneration and its hydrological conditions are taken mostly in moist climate beech stands, which forest stands are preferred for purposes of continuous cover forest management. Manninger (2008) said that in the gaps and in closed forest there are differences in absolute value of soil moisture, but the directions and values of changing are similar. Gálhidy et al. (2006) said, that the soil moisture was not significantly different in a small and a big gap, but in big gap the values were more diverse and soil moisture was higher in gaps than under the closed stand. Good indicators for soil moisture determination without instrumental measurements are the presence data of herbaceous species. Tobisch (2010) said that height of the tallest sessile oak and hornbeam seedlings was related mainly to the cover of soil moisture indicator herbs.

The aim of the research was to investigate the changing of soil moisture conditions in oak stands in an intensive spatial scale through the whole vegetation period in different gaps.

2 MATERIALS AND METHODS

2.1 Research sites

The research takes place in western Hungary, Vas County. In two sites were soil moisture measurements taken (*Table 1*) in the vegetation period of 2013 and 2014 years.

Table 1 – Research sites.

Forest sub compartment	Forest stand type	Age (in 2014)	Soil type - Hungarian system (World Reference Base)	Hydrology	Physical	Gap opening
Bejcgyertyános 13 A (N47° 11.304', E 17° 0.626')	Sessile oak-hornbeam	84	Lessivated brown forest soil (Vertisol)	free draining	Loam	2010
Vép 32 D (N47° 13.667', E16° 47.307')	Turkey oak	70	Surface water gley brown forest soil (Vertisol)	free draining	Loam	2010

In every site, there are three parcels, each with 0.25 ha (50x50 metres) area, two similar size artificial forest gaps and one control area with close canopy. The elliptical shape gaps are one tree high long and half tree high width (approximately 30x15 metres area), one directed to North-South, and the other to East-West. In each gap and the surrounding closed forest stand 41 plots, while in the control area 16 plots were set in constant pattern (*Figure 2*). In data processing, plots in the parcels with gap were categorised as middle of the gap (13-15, 19-23, 27-29 plots, n=11), sides of the gap (8-11, 17-18, 24-25, 31-34 plots, n=12) and above close canopy (1-6, 9, 12, 16, 26, 30, 35-41 plots, n=18).

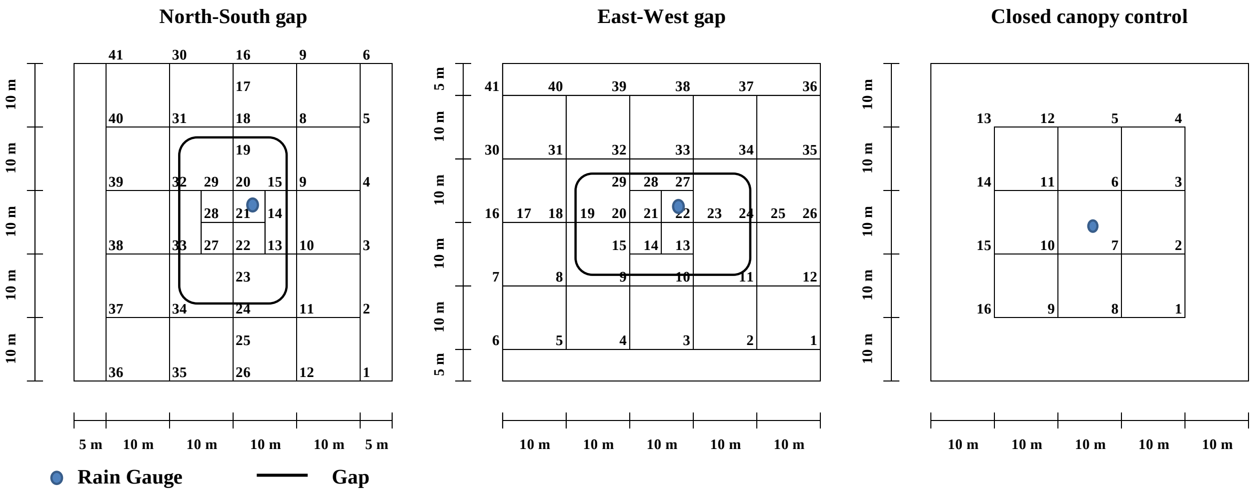


Figure 2 – Experimental design of gap and control parcels.

2.2 Field methods

Field Scout TDR 300 Soil Moisture Meter was used in the research. Soil moisture is a critical and potentially highly variable component of the soil environment. Time-domain reflectometry is a proven technology for quickly and accurately determining volumetric water content (VWC) in the soil. The Field Scout's shaft-mounted probe allows the user to easily and rapidly take many measurements. The user can quickly transition between taking VWC readings in standard and high-clay mode. The meter's built-in data logger can record data from several sites and eliminates the need to record data manually. Through the software (included) the user can download the data, change the logger settings and program the logger to record relative water content at multiple sites (Spectrum Inc., 2009).

To get Volumetric Water Content data from Field Scout TDR 300 Soil Moisture Meter, in the experiment data collection mode was set to default calibration for standard soils. Soil specific calibration was not performed. In every plot, four soil moisture measurements were taken per field day.

For the aspect of soil moisture, it is necessary to know the quantity of precipitation, which was measured in the centre of the parcels, with rain gauge. Precipitation was measured in time of soil moisture measurements, about one- or two- week periods. The received periodical precipitation was converted into daily precipitation with free access meteorological data downloaded from the internet (http://www.idokep.hu/csapadek). For each day, data was writing out of precipitation map near Sárvár. From these periodical precipitation was calculated for the same periods, as was measured in the field. With the help of daily precipitation data, the field periodic data was proportioned to daily data. These daily precipitation data are shown in *Figure 4*.

In time of experimental design planning, the aim was to analyse the deepest soil depth available. The Field Scout TDR 300 Soil Moisture Meter can analyse four different soil depths with different length rods. The available depths are 20 cm, 12 cm, 7.6 cm, 3.5 cm. After field experiences, depth lengths had to be decreased. The 20 cm log rods were soon broken in forest soils (about after 700 measurements a rod was broken). The 12 cm long rods were good enough for moist soil conditions, but in a drought summer they had to be changed frequently (about after 1500 measurements a rod was broken). The most reliable rod length was 7.6 cm, in which case no rods ever broke. 3.5 cm rods were not used.

Because in the first year analyse depths were changed more times, to standardise the data, comparison measurements were taken in 2014 from spring till summer in Bejcgyertyános 13 A forest subcompartment control parcel, when in 8 constant control plots measurement were taken with all available rod lengths (20 cm, 12 cm, 7.6 cm, 3.5 cm).

2.3 Statistical analyses

The first step of analyses was to standardising the soil moisture data came from different soil depth (*Figure 3*). Average values of daily soil moisture data were presented in diagrams. To model the seasonal change of soil moisture, trend lines were drawn and R^2 calculated to found out how well the model fits the data (*Figure 4*). After that Analysis of Variance (ANOVA) tests and T-tests were made to find significant differences between parcels or parts of a gap (*Table 2*).

3 RESULTS

3.1 Standardising soil moisture data

The standard soil depth for analysis was defined as 7.6 cm, upon this was converted the other rod length measurements with converter equations. 20 cm and 12 cm deep Volumetric Water Content data were paired with 7.6 cm deep data, and these results were plotted in a diagram. Trend lines were drown for these pairs to found out the best fitted function (R^2, and equations). The final converter equations (power function) are shown in *Figure 3.* It is evident that the upper level of soil is moister than the lower levels.

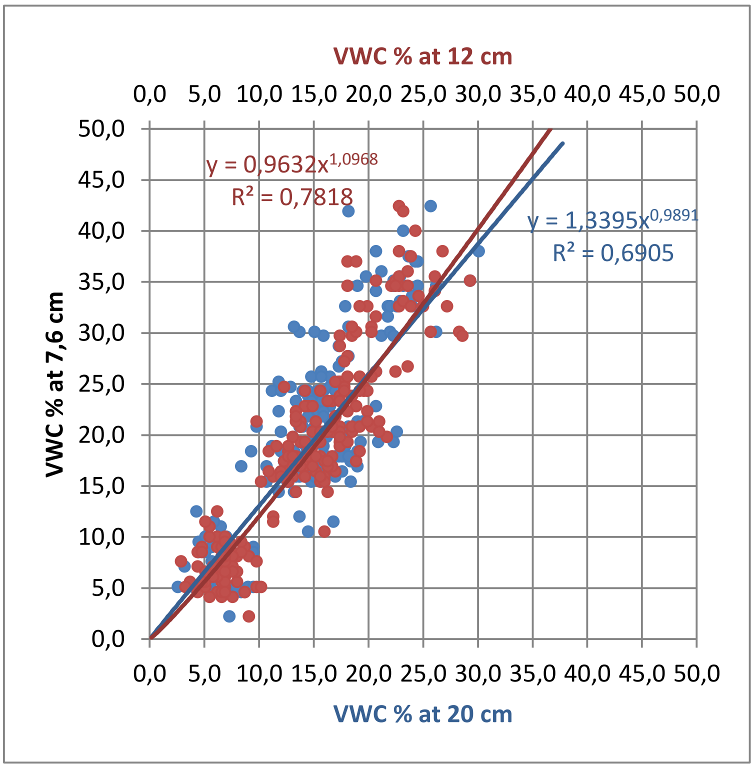


Figure 3 – Converting equations from 20 cm and 12 cm to 7.6 cm rod length.

3.2 Temporal changes in soil moisture

Between 08 April 2013 and 06 October 2014, in two vegetation periods 37 field trips were made. This much work had about 30000 measurements with the Field Scout instrument. The two vegetation periods have a great variance in precipitation. While in 2013 from April to October there was an average of 265 mm precipitation, in 2014 in the same period precipitation was 444 mm. These weather conditions had a great influence on soil moisture, which is to be shown in *Figure 4* in a chosen parcel (Vép 32/D forest sub compartment, North-South directed gap). In the figures trend lines show the modelled temporal soil moisture changing.

If set *Figure 4 (a)* against *(b)* the changing frequency of precipitation is outstanding in the two different years. While in 2013 rarely, about one or two weekly period rainy days appeared, with a maximum of 17 mm, in 2014 the rainy days were more frequent, and concentrated, lasted for days or almost a week. From the influence of these, in 2013 an extended drought period was experienced between July and October. In 2014 only June was rainless, when soil moisture dropped, but after that short dryer period, soil moisture was rising fast. By the beginning of September, soil moisture reached its maximum, while in 2013 the soil could not reach this saturated phase by the end of October. In the figures R^2 are shown. These values are higher in 2013, than in 2014.

In 2014 the measurements were a bit less frequent than in 2013. The reason for decreasing the frequency of measurement days was financial. The average return period in 2013 was 9 days, while in 2014 13 days. Also in 2014 if a measurement was close to a rainy day, the soil moisture data became outstandingly high (e.g. 19.05.2014 or 07.07.2014).

3.3 Spatial changes of soil moisture

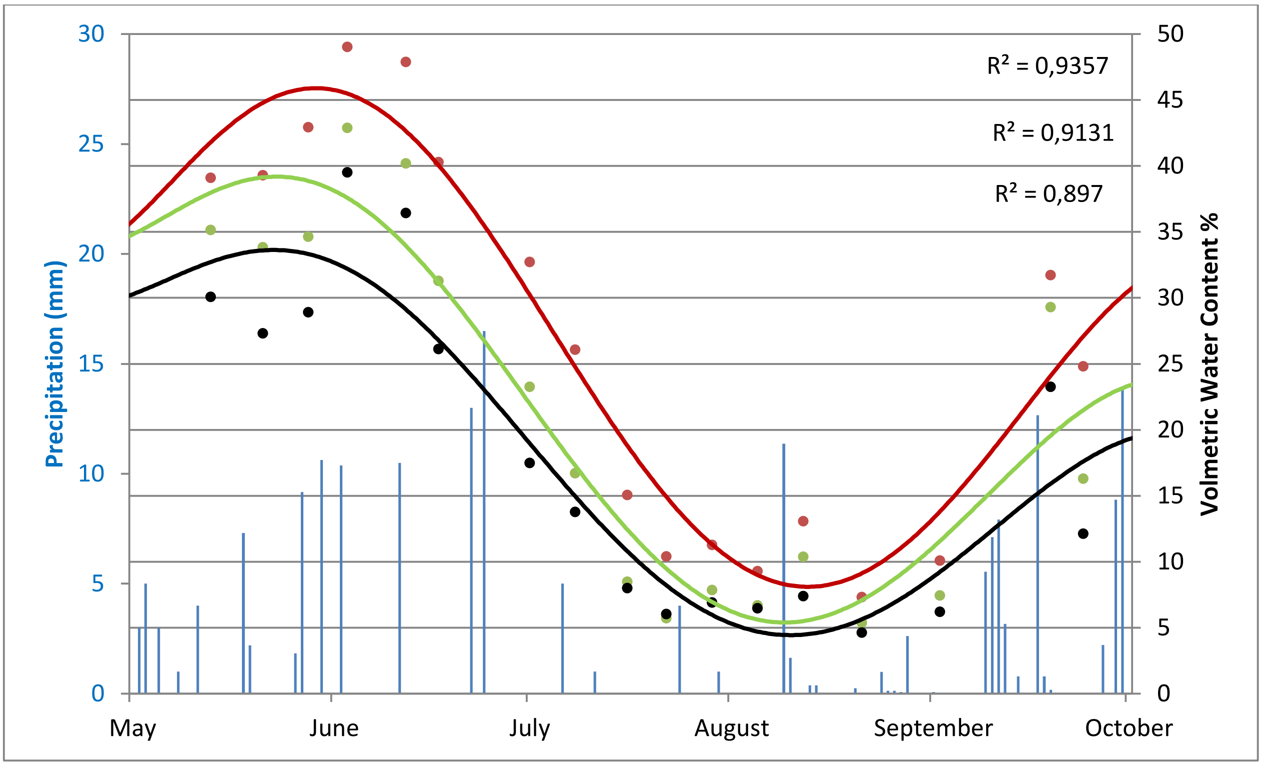
Analysis of Variance (ANOVA) tests were made to find, if there are differences (p<0,001) between three or more groups of means. The mean results of the analysis shows in *Table 2*. T-tests were made in a few cases, where mean values are close to each other to find out if significant differences are present or not within two groups. These cases, where no significant differences found (p>0,001) are marked with grey background in *Table 2*.

Table 2 **–** Mean and standard deviations (in brackets) values of Volumetric Water Content % for all data.

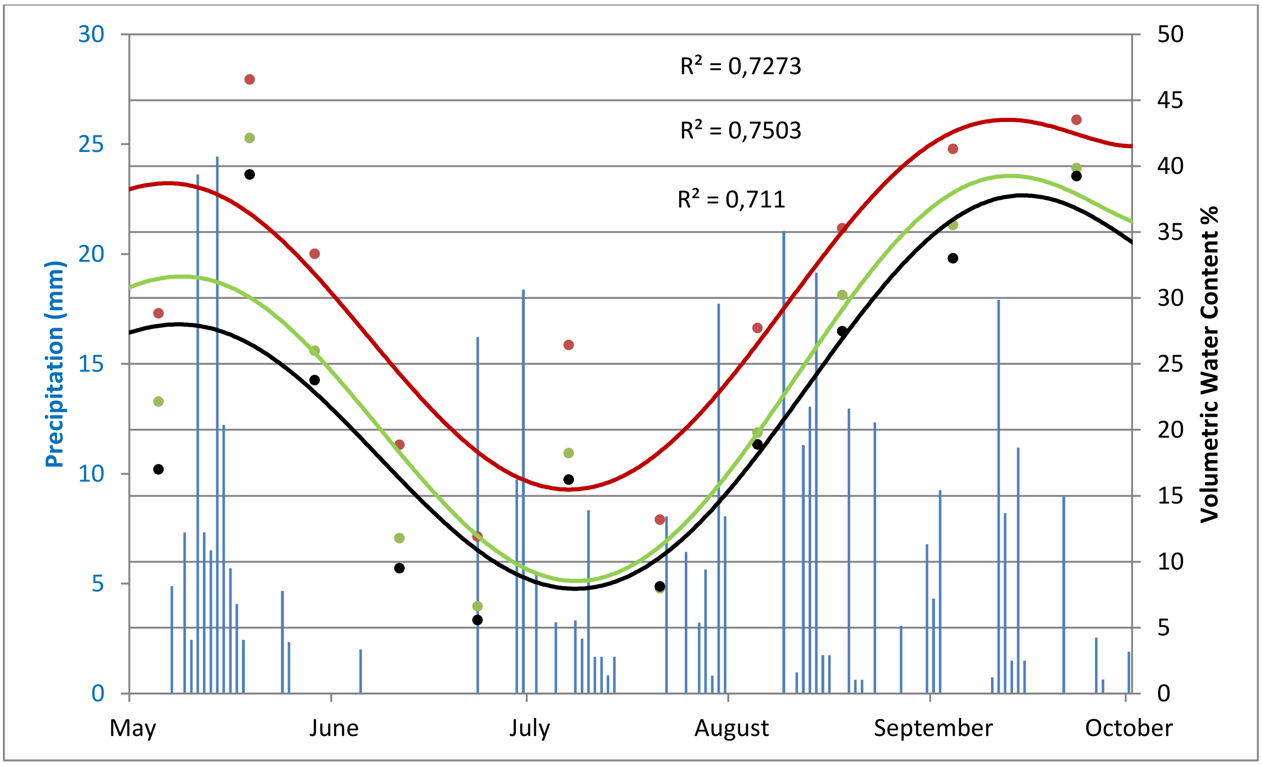
	Bejcgyertyános 13 A				**Vép 32 D**			
	South-North Gap	**East-West Gap**	**Control**	**All Samples**	**South-North Gap**	**East-West Gap**	**Control**	**All Samples**
Middle of gap	24 (10)	30 (12)		27 (12)	30 (14)	28 (14)		29 (14)
Sides of gap	18 (10)	23 (11)		21 (11)	24 (14)	22 (12)		23 (13)
Above close canopy	18 (9)	20 (11)	18 (10)	19 (10)	21 (12)	21 (12)	22 (13)	21 (12)

There are differences in absolute values of soil moisture in the two sites, but tendencies are the same. The mean value of Volumetric Water Content (soil moisture) is 6 percent higher in the middle of a gap than in the sides of it. The soil moisture is additional 2 percent lower above close canopy. It is also seen that standard deviations are decreasing as measurements move towards from the middle of a gap to above close canopy. It is showing the same results as Gálhidy (2006) said, that in a gap the soil moisture values are more diverse.

There are also differences in average soil moisture between the North-South and East-West directed gaps. However, these differences cannot be explained yet.



(a)



(b)

Figure 4 – Vép 32/D, North-South gap average soil moisture (Volumetric Water Content) data in 2013 (a) and in 2014 (b) (middle of the gap: red line, sides of the gap: green line and above close canopy: black line), daily precipitation shows as blue columns.

The experiences of spatial changes can be exemplified in counterplot diagrams. As an example, in *Figure 5* four daily soil moisture diagrams can be seen. The scale of the diagrams shows the Volumetric Water Content with 2% levels. The raw data spikes show the constant pattern of the measurements.

In *Figure 5* clearly have drawn the moister phase of the middle of a gap, which difference is stated in the driest periods. Close to the saturation point of the soil, in spring and fall these differences can decrease, or almost disappear. The water uptake of the still standing mother stand’s rooting area has a great impact on the spatial changes of soil moisture in a gap and its surroundings. These moist phases cannot be compensated by the greater sunlight in that gap size (about 30x15 metres).

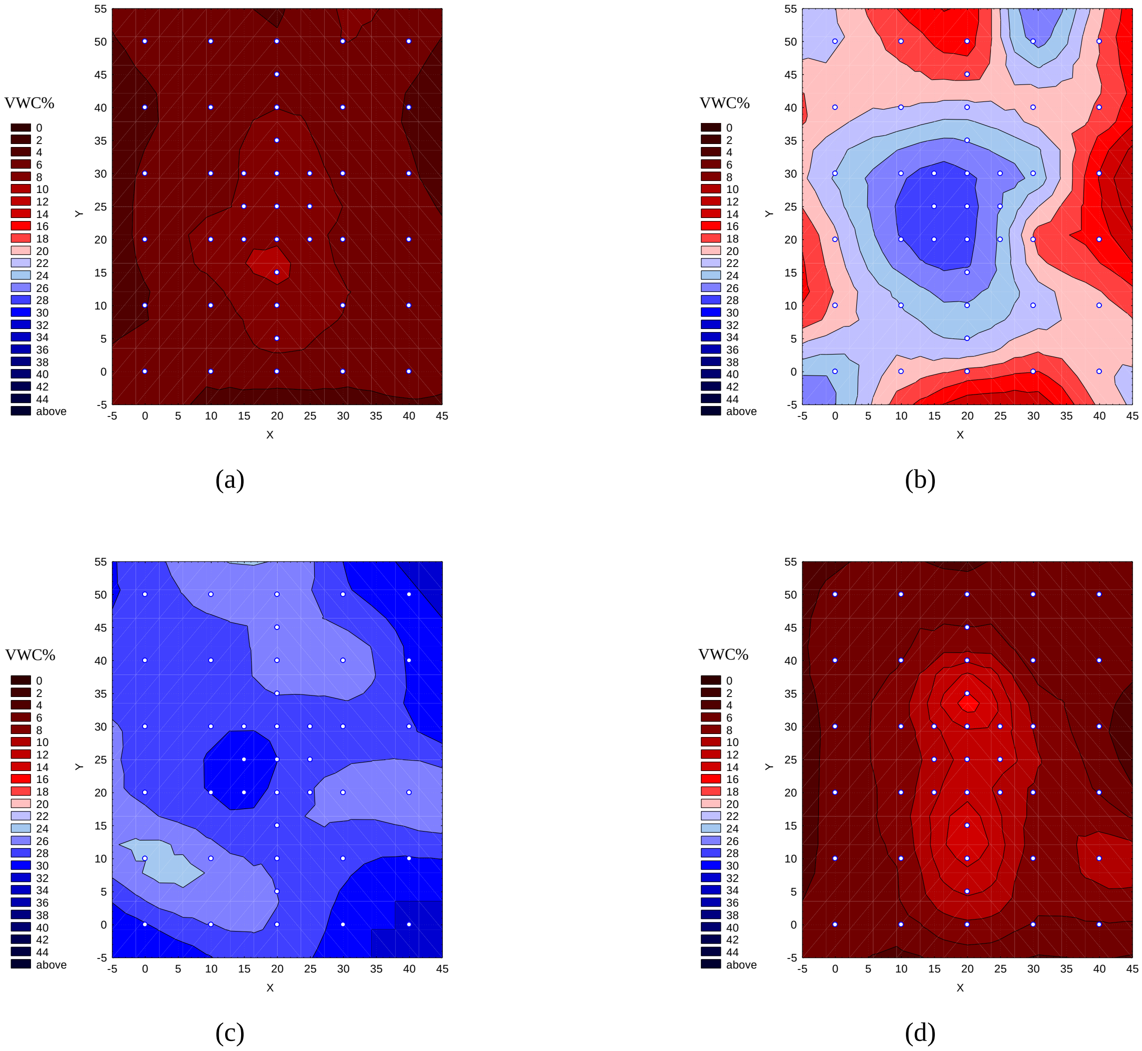


Figure 5 **–** Vép 32/D, North-South gap 21.08.2013: the driest soil phase (a), 15.10.2013: a medium moist soil phase (b), 22.04.2014: moist soil phase (c), 23.06.2014: the driest soil phase in 2014 (d).

4 DISCUSSION

Soil moisture has great temporal and spatial variability in gaps. There are significant differences between different parts of a gap in the research sites. In the middle of a gap Volumetric Water Content is 6 percent higher than in the sides of the gap, and the closed forest stand is also 2 percent lower than the sides of the gap. These differences stand still in dry or moist soil phases.

5 ACKNOWLEDGEMENTS

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